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PHYSICAL AND CHEMICAL CHARACTERISTICS OF SILICA SAND DEPOSITS (WHITE SAND) OF WADI WATIR REGION, SINAI

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ABSTRACT

Preliminary investigation on the silica sand deposits (white sands) of Wadi Watir region shows that they are of well-sorted grain size, considerable purity and high grade. They might be suitable for art and domestic glass manufactories. The present paper shows that only simple screening must be for upgrading of silica sands. Neither acid treatment of the silica sands nor removal of their content of heavy minerals improves the silica sand grade to any extent.

Key words: glass sand deposits, physical and chemical properties, Wadi Watir, Sinai, Egypt

INTRODUCTION

At the request of the new Egyptian factories for white sands, a comprehensive investigation to look for these deposits in Sinai took place in last few years. Silica sand deposits are widely used in glass and ceramic industries. Preliminary estimation shows that the Egyptian glass industries need more than 1500 tons per year of silica sands (Kamel et al., 1997). Computation of silica sand reserves has not been completed.

The present study is the preliminary investigation for about twenty representative samples as an introductory step to do more detailed studies in the near future. To determine the suitability of the silica sand deposits of Wadi Watir region for glass industry, physical and chemical studies are being carried out. Preliminary results indicate that most of these sands may be suitable for the manufacture of art, domestic and optical glass as well.

The main goal is to provide a brief description of the chemical composition, grain size and heavy mineral content of the silica sands. In addition, its chemical composition is compared with some samples collected from the present day beach sands of Gulf of Aqaba coast. The upgrading processes of silica sands through laboratory experiments are presented and evaluated.

Khalid (1993) studied the economic mineral deposits including; gold and

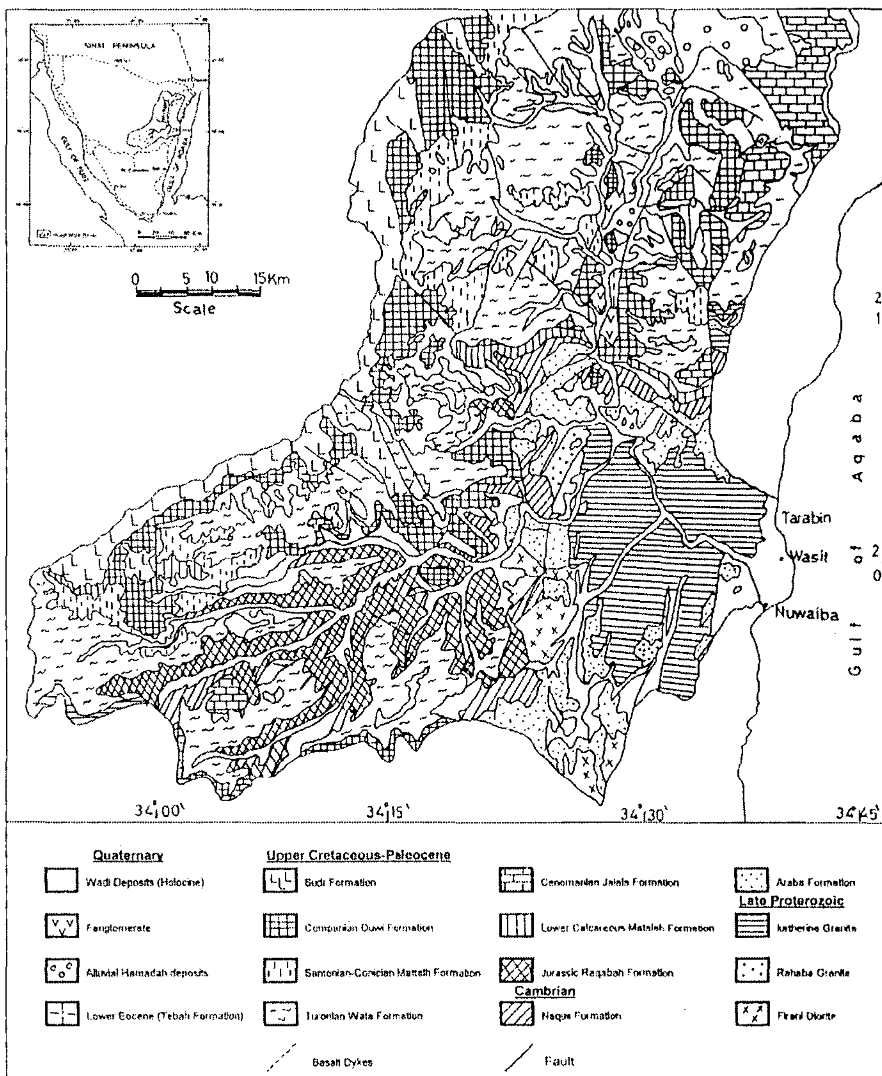

Fig. 1. Geological map of Wadi Watir, South Sinai, Egypt. (After Geological Survey of Egypt, 1994)

white sands of the Nuweibe area, south Sinai. El Fawal (1994) and Kamel et al (1997) shed some light on the economic accumulations of these sands within the Carboniferous Abu Tora Formation, west-central Sinai. Abu Shabana (1998) estimated the reserve of the glass sands at Abu-Rodeiyim and Abu-Heish localities, west-central Sinai to about 8 million tons.

The area under investigation is located to the west of Nuweiba city, west of the Gulf of Aqaba. It lies between latitudes 29° 10' and 28° 55' N, and longitudes 34° 17' and 34° 35' E (Fig. 1). The silica sand deposits occur within the Naqus Formation of Early Paleozoic age. The stratigraphic definition of Naqus Formation was introduced by Said (1971) after Hassan (1967) describing a thick siliciclastic sequence, attaining 250 m thick. It unconformably overlies the Araba Formation and is overlained by the Malha Formation. Twenty representative samples were collected from the Naqus Formation that cropping out across Wadi Ghazalla, from the south outlet of the wadi at the north side of Katherina-Nuweiba asphaltic road to the north direction (Figs. 1 and 2). In the studied section the Naqus Formation measures 70-100 m of white sandstones. They are devoid of any organic remains, indicate fluvial deposition as reported by Issawi and Jux (1982). The lower and middle parts of the section are fine to medium white, massive and thick bedded sandstone with occasional thin bands of coarse grained sandstone. The upper part of the studied section is mainly white to light grey, friable to slightly hard, fine grained sandstones. The most striking feature distinguishing the sequence is Mashrabia structure of fenester structure (Fig. 3) and ripple marks as well as quartz pebbles which distributed randomly or parallel to the bedding planes. Ferruginous bands are also common.

Watir area is characterized by some big, wide and flat domal structures dissected by long faults (Fig. 1) which have dominantly strike-slip movements. The main faults are meridionally directed, commonly hidden by smaller faults. Near Aqaba, most of these faults have NE and NS trends. NW faults (Suez trend) are of less extension. The intersection of these set of faults with equatorial faults resulted in forming the very rugged topography in the sedimentary blanket of Watir area as along the course of wadi Ghazalla (South Sinai water resources project, 1995).

Fig. 2. Naqus Formation underlying Cretaceous rocks, across Wadi Ghazalla

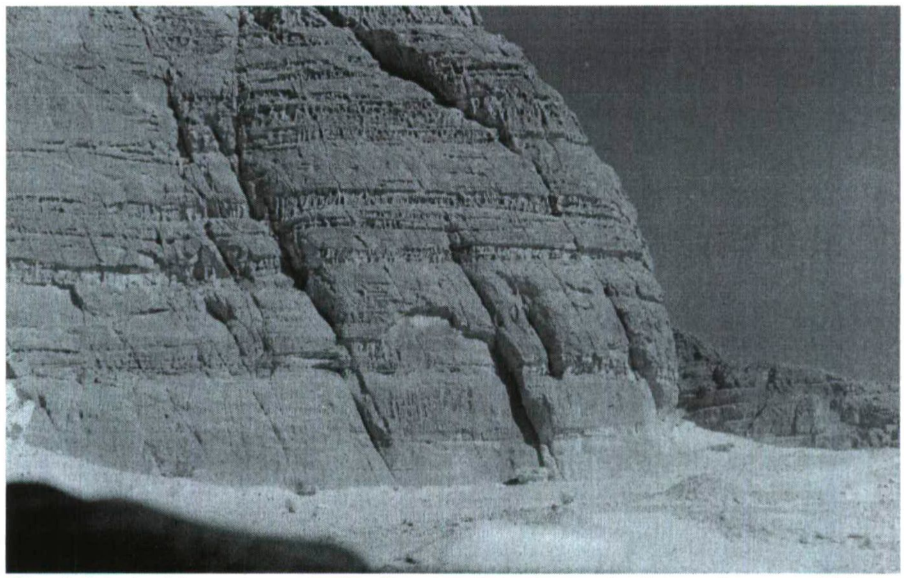

Fig. 3. Mashrabia structure is the characteristic feature int he sandstones of Naqus Formation, Wadi Ghazalla, Southeastern Sinai

LABORATORY METHODS AND FINDINGS

Screen Analysis

The samples are quartered. A representative dry sample of about 100 gms is taken out of each original sample. Weighted amount is sieved 30 min through a set of sieves with opening diameters of 2.0, 1.0, 0.5, 0.250, 0.125, and 0.063 mm; using sieve shaker. The average result of twenty samples is plotted on a histogram as shown in Figure 4. It shows that the silica sands are very well-sorted; more than 90% of the grains are with grain size of 0.125 to 1.00 mm; coarse to fine sand range. More than 50% of the grain size is within 0.25 to 1.00 mm which is within the medium to coarse sand range (Table 1A).

Mineralogical Composition

The sieved fractions are examined under the binocular microscope to study their physical and mineralogical properties (Table 2). It is observed the bulk fractions composed essentially of single quartz grains, with few polycrystalline quartz grains and small amounts of heavy minerals. The coarser grains (0.5 mm) are usually sub-rounded whereas the finer-grains (0.125 mm) are angular. The impurities are: heavy minerals, dark-grey polycrystalline quartz; in contrast to clean white quartz grains.

Table 1. Result of screen and chemical analyses of bulk samples and 1.00-0.125 mm fractions of silica sand from Wadi Watir region

(A) Screen Analyses										
sample no./mm sieve	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
over 2.00 mm	nil	0.3	nil	0.1	nil	1.2	0.1	nil	nil	0.1
2-1 mm	3.2	15.4	0.7	4.3	3.8	36.0	1.00	3.72	0.8	4.2
1-0.5 mm	20.3	21.2	5.4	18.0	16.0	19.4	14.3	23.8	1.2	13.5
0.5-0.25 mm	69.2	55.3	70.7	71.0	66.2	26.9	62.4	61.0	50.8	70.4
0.25-0.125 mm	6.8	7.0	21.5	5.3	12.7	11.8	19.8	9.2	39.7	9.1
0.125-.063 mm	0.1	0.3	1.0	0.3	0.8	0.4	1.4	1.08	5.26	1.3
<0.063 mm	0.1	0.2	0.7	0.5	0.5	0.1	0.8	0.7	2.18	0.6
(B) Chemical analyses of bulk samples (%)										
sample no./oxides	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
L.O.I.%	0.22	0.25	0.19	0.34	0.13	0.48	0.28	0.29	0.12	0.20
SiO_2	98.62	97.93	98.01	97.53	99.38	97.96	98.19	98.39	99.34	98.59
Fe_2O_3	0.04	0.07	0.03	0.08	0.03	0.08	0.08	0.09	0.04	0.06
TiO_2	0.16	0.10	0.07	0.17	0.06	0.21	0.20	0.17	0.09	0.04
Al_2O_3	1.02	1.84	1.79	1.92	0.41	1.29	1.28	1.09	0.50	1.26
CaO+MgO	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Total	100.06	100.19	100.09	100.04	100.01	100.02	100.03	100.03	100.09	100.15
Grade**	5	7	3	7	2	7	7	7	2	5
(C) Chemical analyses of chosen 1.00-0.125 mm fractions										
L.O.I.%	0.14	0.18	0.13	0.22	0.12	0.32	0.20	0.19	0.10	0.12
SiO_2	99.04	98.81	98.87	98.63	99.45	98.08	99.27	99.02	99.43	99.61
Fe_2O_3	0.01	0.03	0.02	0.03	0.02	0.02	0.01	0.05	0.02	0.02
TiO_2	0.10	0.16	0.11	0.24	0.08	0.27	0.21	0.19	0.11	0.10
Al_2O_3	0.12	0.20	0.27	0.25	0.05	0.17	0.30	0.35	0.18	0.14
CaO+MgO	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr	Tr
Grade**	2	3	2	3	2	2	2	4	2	2

Grade**: Based on U.S. specifications, chemical composition only. Tr: < 0.1% L.O.I. % Loss of Ignition

Heavy Mineral Analysis

Bulk samples are subjected to heavy mineral separation using Bromoform solution. The heavy fractions are washed and dried. Percentage of heavy fractions from selected samples calculated. It ranges from trace to about 0.5%. The dominant minerals are opaque minerals, zircon, rutile and tourmaline. Zircon ranges in abundance from 2 to 10.5%, tourmaline from 2.5 to 5.5% and rutile from 1.5 to 3.5% by weight of the heavy fractions. Biotite, staurolite, epidot and apatite found in trace amounts.

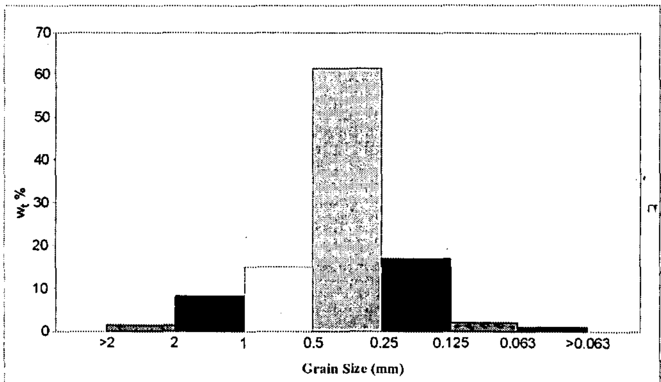

Fig. 4. Grain size distribution in 20 samples of silica sands

CHEMICAL UPGRADING PROCESS

Chemical composition of bulk sample and chosen fraction:

Initially chemical analysis was done on the bulk samples by XRF technique. The results of the chemical composition of ten bulk samples are given in Table 1B. It shows that SiO_2 ranges from 97.53 to 99.38% representing the most abundant oxide in the studied samples. From visual examination of the various fractions under the binocular microscope, it was observed that the main impurities distributed throughout coarser and finer fractions. Therefore, the analysis of chosen fractions might upgrade the silica sands for glass manufacture. The chosen fractions are with grain size of 0.125 to 1.00 mm. Chemical compositions on the chosen fractions for the same samples show a slight improvement of SiO_2 content (from 98.87 to 99.61%) and lower content of the undesirable impurities compared with the bulk samples. The results are shown in Table 1C.

Table 2. Physical and mineralogical properties of the fractions

+2.00 mm	Sub-rounded white quartz grains, a few polycrystalline grains and dark-grey rock fragments. More than one quartz grains with fine ilmenite embedded.
+1.00 mm	Sub-rounded to sub-angular white quartz grains. A trace of grey to light-brown polycrystalline quartz. Few embedded ilmenite grains in quartz.
+0.50 mm	Similar to above.
+0.250 mm	Angular to sub-angular quartz grains, white, very clean. Few grains of dark-grey polycrystalline quartz.
+0.125 mm	Angular white quartz grains. Trace amounts of heavy minerals: iron oxides, ilmenite and zircon.
+0.063 mm	Angular, white and pink quartz grains. Minor percent of heavy minerals 2%.
-0.063	About 5% heavy minerals. Angular quartz grains.

Chosen fraction free from heavy minerals:

Although heavy minerals occur in trace amount in the silica sand (Less than 0.5%), their Fe_2O_3 content may affect the overall grade of the silica sand. Therefore the chemical analyses were done on eight samples of 0.125 mm-1.00 mm fraction after the removing of the heavy minerals. It was carried out to show whether removal of the heavy minerals would improve the grade of sands or not, in terms of glass manufactory. The obtained results indicate that the removal of the heavy minerals from 0.125-1.00 mm fraction does not improve the grade and composition to any extent. The results are shown in Table 3A.

Acid treatment of sands:

Because some of sand grains have iron oxides coatings, the treatment with acid may be able to dissolve the surface films or stains. Six samples of 1.00-0.125 mm fraction free from heavy minerals were immersed in 10% hydrochloric acid for 24 hours. The results are shown in Table 3B. The obtained result shows that acid treatment of white sands does not intensively reduce the Fe_2O_3 content.

General specifications and standards for Glass Sands

Generally, the glass sand is graded according to its silica and alumina contents. The percentage content of lime, magnesia may also taken in consideration. Specifications vary within certain limits from one glass manufacturer to another and also from country to another one as shown in Tables 4 and 5. For example sands containing more than 99.5% SiO_2 and 0.1% Al_2O_3 are considered of high grade and may be suitable for optical purposes.

Table 3. Chemical analyses of 0.125-1.00 mm fraction of silica sands without heavy minerals and acid-treated samples

(A) Chemical analyses of 8 selected samples after heavy minerals removed								
Sample No. Oxides	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
L.O.I.%	0.16	0.16	0.17	0.20	0.19	0.21	0.19	0.17
SiO_2	99.02	98.75	98.68	99.60	99.47	98.42	99.31	99.01
Fe_2O_3	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
TiO_2	0.01	0.02	0.03	0.04	0.02	0.14	0.04	0.04
Al_2O_3	0.14	0.12	0.11	0.12	0.13	0.14	0.19	0.21
CaO+MgO	t	t	t	t	t	t	t	t
Grade**	2	2	2	2	2	3	2	2

(B) Chemical analyses of acid treated of above 6 samples						
L.O.I.%	0.14	0.15	0.11	0.16	0.16	0.18
SiO_2	98.91	98.71	98.60	99.57	99.45	98.36
Fe_2O_3	0.02	0.02	0.01	0.02	0.02	0.01
TiO_2	0.01	0.01	0.02	0.01	0.01	0.01
Al_2O_3	0.25	0.19	0.16	0.25	0.25	0.16
CaO+MgO	t	t	t	0.1	t	t
Grade**	2	2	2	2	2	3

Grade** U.S. specifications, based on chemical compositions, t < 0.01% L.O.I. % Loss of Ignition

Table 4. Specifications for chemical composition for glass sand**

	SiO_2 % (Min.)	Al_2O_3 % (Max.)	Fe_2O_3 % (Max.)	CaO+MgO % (Max.)
1st quality (optical glass)	99.8	0.1	0.02	0.1
2nd quality (flint containers and table ware)	98.5	0.5	0.035	0.2
3rd quality (flint glass)	95.0	4.0	0.035	0.5
4th quality (sheet and plate glass)	98.5	0.5	0.06	0.5
5th quality (same)	95.0	4.0	0.06	0.5
6th quality (green glass, containers and windows glass)	98.0	0.5	0.3	0.5
7th quality (green glass)	95.0	4.0	0.3	0.5
8th quality (amber glass containers)	98.0	0.5	1.0	0.5
9th quality (amber glass)	95.0	4.0	1.0	0.5

**Recommended by the American Ceramic Society and the National Bureau of Standards (Norton, 1957)

Table 5. Iron oxide standards set by glass manufactures*

Product	Maximum Fe_2O_3 %
Optical glass	0.015-0.016
Containers (colourless)	0.03-0.04
Containers (amber)	0.05-0.08
Plate glass (general)	0.15
Plate glass (windows)	0.08

*Reported by Ceramic Industry Magazine (1966)

CONCLUSIONS

The results of the grain size, heavy mineral content and chemical composition of the Wadi Watir silica sand deposits (white sands) indicate that:

1. The silica sand deposits are very well-sorted, more than 90% of gains lie between coarse to fine sand size range. They consists essentially of white and clean single, sub-rounded to angular, quartz grains. The impurities are represented by heavy minerals, coloured polycrystalline quartz grains and iron oxides occurring in the micro-coatings.

2. Heavy mineral assemblage includes opaque minerals, zircon, rutile, andalusite and tourmaline.

3. The acid treatment of glass sand by dilute hydrochloric acid the removal of the heavy minerals not improve the grade of silica sands to any extent. Simple process of screening may be the most effective method of upgrading the silica sand and can be applied to larger extent on other accumulation of these sands.

4. Most of the silica sand deposits of Wadi Watir region are of second and third grade according to the U.S. specifications (Norton, 1957). They can be suitable for the making art domestic glass. According to the report of the ceramic industry magazine (1966), silica sand deposits used for making containers must have 0.03-0.04% Fe_2O_3. In addition the present study refers that beach sands from Gulf of Aqaba coastal plain are generally not suitable for glass manufactures.

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